

**Incorporating information on bottlenose dolphin distribution into Marine
Protected Area design**

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2 **ABSTRACT**

3 1. The steady growth of the whale-watching activities in the Azores and its
4 concentration in a small area that partly overlaps the home range of a resident group of
5 bottlenose dolphins (*Tursiops truncatus*) was one of the driving forces to proposing part
6 of the range of this group as a Marine Protected Area (MPA).

7 2. We used 6-years of data collected during boat surveys to investigate how dolphins
8 used the candidate MPA (cMPA) and whether they showed any preference for the
9 cMPA over adjacent areas. We also estimated the fraction of the resident individuals
10 and group's range included in the cMPA and examined whether there were any
11 temporal changes in its use.

12 3. Mean daily encounter rate of bottlenose dolphins was higher inside than outside the
13 cMPA. Dolphin sightings inside the cMPA were nearly double than what was predicted
14 by the survey effort. Dolphins used the cMPA with similar intensity throughout the
15 years.

16 4. Resident dolphins were frequently sighted in the cMPA. However, less than 20% of
17 the known range (650 km²) and 41% (39 km²) of the core area of the group lay within
18 the cMPA. The reliability in the use of the cMPA over a 6-year period suggests its
19 importance for the dolphin population remained relatively stable but its surface area was
20 clearly insufficient to satisfy the spatial requirements of the resident group.

21 5. Based on these findings, we proposed to the Regional Government of the Azores to
22 extend the boundaries of the cMPA. Accordingly, the modified protected area
23 established in 2008 includes 100% of the core area of the resident group of bottlenose

dolphins. This study provides an example of how information on cetacean habitat-use patterns may be used to design ecologically meaningful protected areas for this group.

Keywords: Ocean; Islands; Marine Protected Area; Distribution; Protected Species; Mammals

INTRODUCTION

Spatial-based conservation measures are increasingly used to manage fish resources and to protect marine habitats and threatened species (Hyrenbach *et al.*, 2000). Traditionally, marine protected areas (MPAs) have been used to protect nearshore habitats and sessile or benthic organisms. Recently, significant attention has been given to the application of this concept to offshore waters and to wide-ranging species, such as large pelagic fishes, marine mammals, seabirds and marine turtles (Hooker and Gerber, 2004; Game *et al.*, 2009). Although the number of MPAs established to protect cetacean populations has been increasing worldwide (see Hoyt (2011) for a recent review), there is still much debate on whether spatial-based management is appropriate for these highly mobile organisms (Game *et al.*, 2009). Cetaceans usually have ranges that are too large to be encompassed within an MPA and the effectiveness of protecting species in only parts of their range has often been questioned. However, species may benefit from increased protection at more vulnerable stages of their life cycles, and MPAs can be designed to include the population's breeding or foraging sites, or migratory routes (Hooker and Gerber, 2004; Game *et al.*, 2009). Alternatively to, or in conjunction with this approach, MPAs may be placed in areas where threatening human activities significantly overlap with the population's

1 range or important habitats (Game *et al.*, 2009; Ashe *et al.*, 2010). However, identifying
2 important areas for cetaceans is not straightforward and variability in cetacean space-
3 use patterns presents enormous challenges to protected area design.

4 Along the continental margins, bottlenose dolphins (*Tursiops truncatus*) usually
5 occupy coastal or inshore areas and maintain well-defined ranges. Theoretically, these
6 characteristics make the bottlenose dolphin a suitable candidate for spatial-based
7 conservation efforts. Yet, Wilson *et al.* (2004) illustrated the difficulties of designing
8 MPAs for this species. The inner Moray Firth (Scotland) was proposed as a candidate
9 Special Area of Conservation (cSAC) under the Natura 2000 network, to protect a
10 resident population of bottlenose dolphins (McLeod *et al.*, 2005). The boundaries of the
11 area were based on data collected in the 1980s and early 1990s and included the
12 majority of the population's then known range (Wilson *et al.*, 1997). A few years later,
13 Wilson *et al.* (2004) showed that the population had expanded its range and the SAC
14 might no longer be as effective in protecting the resident dolphins.

15 Thus, protected area design requires good knowledge of the spatio-temporal
16 distribution and habitat requirements of the population of interest in order to scale the
17 size of the management unit to the biological scales in which the population functions.
18 This does not exclude the need to periodically assess the effectiveness of the area and, if
19 necessary, to review its design to adapt to the population movements and behaviour.

20 Here, we present an example of a “phased-design” of a MPA in the Archipelago
21 of the Azores, in which novel scientific information on the distribution and habitat
22 requirements of bottlenose dolphins was used to inform ongoing conservation actions
23 from the Regional Government of the Azores. We identified important habitat areas for
24 the population of bottlenose dolphins in the study area, examined the potential value of

1 a candidate MPA (cMPA) to protect this population, and describe how these findings
2 were incorporated into the design of this protected area.

3 In 2001, three small areas in the channel between the islands of Faial and Pico
4 were designated as Sites of Community Importance (SCI) within the framework of
5 European Union's (EU) Habitats Directive. Sighting and photo-identification data
6 collected in 1999 and 2000 indicated the channel was frequently used by bottlenose
7 dolphins; among these, a small group of individuals showed some degree of site fidelity,
8 and could be residents there (Tempera *et al.*, 2001a; Silva *et al.*, 2003). Despite their
9 ecological value, the SCI were considered too restricted and confined to coastal areas to
10 have a significant impact on the protection of the habitats and species therein, especially
11 on the bottlenose dolphins (Tempera *et al.*, 2001a). At the end of 2001, the Regional
12 Government of the Azores accepted a proposal to extend the designated SCI to the
13 whole channel between the two islands and to create a single protected area (hereafter
14 called cMPA) (Tempera *et al.*, 2001b). It was intended as a multiple use MPA with a
15 broad range of objectives, in which the conservation of priority habitats, vertebrate and
16 invertebrate species, needed to be in balance with the preservation of a small-scale
17 traditional hand-line fishery and emerging eco-tourism activities, such as scuba-diving
18 and whale-watching (Tempera *et al.*, 2001b).

19 Hence, affording protection to the population of bottlenose dolphins was not the
20 only motivating force for the proposal of this protected area. Nonetheless, the cMPA
21 was viewed as a useful tool to manage potential disturbance from the cumulative impact
22 of a fast-growing whale-watching activity and its concentration in a small geographic
23 area that partly overlapped the resident group's known range (Tempera *et al.*, 2001b).
24 Accordingly, the boundaries of the cMPA were defined to include the region where the

1 highest concentration of sightings of bottlenose dolphins was recorded during those two
2 years (Tempera *et al.*, 2001b). However, it was immediately recognized that the
3 information available was insufficient to understand the spatial requirements of this
4 population. Recommendations were made to continue monitoring the population and to
5 review the boundaries of the cMPA in the near future (Tempera *et al.*, 2001b).

6 Recently, Silva *et al.* (2009) estimated that approximately 600 bottlenose
7 dolphins (312 adults, CI: 254-384; 300 subadults, CI: 232-387) occur around the islands
8 of Faial and Pico in a single year. Of these, only 44 dolphins were identified as residents
9 in the area, based on their long-term and year-round site fidelity (Silva *et al.*, 2008).
10 Examination of the ranging behaviour of 27 resident dolphins showed that the channel
11 between the islands of Faial and Pico was part of the core of their home range (Silva *et*
12 *al.*, 2008). Here we assess the importance of the area to this population in light of new
13 information obtained after the cMPA was proposed. Data on the relative abundance of
14 bottlenose dolphins, collected during systematic and opportunistic boat-based surveys,
15 are used to investigate how the species used the cMPA and to assess whether it showed
16 any preference for the cMPA over neighbouring areas. Photo-identification data
17 collected from 1999 to 2004 are used to quantify the usage of the cMPA by the resident
18 group and to examine whether the cMPA includes important areas of habitat for this
19 small group. Finally, we discuss the usefulness of the cMPA as a tool to manage human
20 activities and thus provide protection to the population of bottlenose dolphins and
21 describe how the findings here reported were incorporated into the final design of the
22 cMPA.

24 **METHODS**

Study area

The Archipelago of the Azores (Portugal), located between 37° to 41° N and 25° to 31° W, consists of nine volcanic islands divided into three groups. The study area included the cMPA (123 km²) and the adjacent area surrounding the islands of Faial, Pico and São Jorge (5277 km²) (Figure 1). The cMPA is centred on and encompasses the whole channel between the islands of Faial and Pico, and includes a narrow fringe (4 km long and 3 km wide) along the southern coast of Faial. The channel is 6–8 km wide and 12 km long, with a maximum depth <200 m and an average depth of 70 m. The flanks of this inter-island shelf drop steeply to depths of 1500 m to the north and 900 m to the south (Tempera, 2009). This creates a distinctively characteristic shallow water structure within the study area where islands shelves are narrow and seafloor between the islands typically exceeds 1000 m depth.

Field methods and dataset

Data on cetacean sightings and effort were collected during systematic surveys conducted by the University of the Azores and opportunistic surveys conducted by the observers of the Azores Fisheries Observer Program (POPA). Surveys covered the whole Archipelago of the Azores but in this work we only analysed data collected in the study area.

Systematic surveys were conducted from March 1999 to October 2004. Surveys followed a pre-determined track, either alongshore at 1 km from the coast or in a zig-zag pattern up to 8 km from the islands, and were designed to ensure consistent coverage within the study area. Surveys were conducted throughout the year although most of the effort was made during spring and summer months due to better weather

conditions. Surveys were carried out from a 5.5 m rigid inflatable boat or from a 12 m fibreglass boat, at an average speed of 21 km h⁻¹ (SD = 4.2). During surveys, between three and four observers searched for dolphins and collected data on effort and weather conditions. Surveys were only conducted in Beaufort sea states ≤3. When dolphins were encountered, we recorded the initial time and location, size, composition and behaviour of the school, after which we attempted to obtain several photographs of both sides of every dolphin present in the school. Once photographic data had been collected, we abandoned the dolphin school and resumed surveying from that location.

Photographs were graded ‘Good’, ‘Fair’ and ‘Poor’. “Good” quality photographs were in focus, well exposed, with the whole dorsal fin visible, oriented parallel to the photographer and occupying most of the frame. “Fair” and “Poor” photographs were considered of lower quality and were not used in this study (Figure 2). Individual animals were identified based primarily on the number and location of nicks and scars on their dorsal fins, but also on the scars and pigmentation pattern along the flanks. Small calves and dolphins with few distinct marks or bearing marks judged to be only temporary were not included in the dataset.

POPA is responsible for placing observers aboard tuna vessels aiming to achieve a minimum of 50% coverage of the fleet. Contracted observers receive intensive training on fishing gear and operations, identification of tuna, cetacean, seabird and turtle species (Silva *et al.*, 2002, 2011). A single observer was assigned to each vessel for a 30 day period, after which observers rotated between fishing vessels. Cetacean surveying was only conducted when the vessel was travelling or searching for tunas, at an average speed of 18 km h⁻¹ (SD = 1.8). During a cetacean watch the observers stood on the bridge and scanned the area ahead of the vessel with binoculars and by naked

eye. Data on weather and sea conditions and on the position, speed and heading of the vessel were collected every 30 minutes and whenever the vessel changed course. At each sighting, observers recorded the initial time and location, species and estimated number of individuals in the school. The information was recorded on standardized data sheets and incorporated into a database. Data collected during periods of Beaufort sea states >3 were eliminated from the dataset. Data used in this study were collected from May to October, between 2001 and 2004.

Distribution and patterns of habitat use inside and outside the cMPA

Data collected during systematic and opportunistic surveys were initially treated separately. Sighting locations of bottlenose dolphins and survey tracks of the research boat and of fishing vessels were plotted using *ArcGIS*[®] 9.0. Survey effort was measured as the number of kilometres travelled in adequate sighting conditions, i.e. Beaufort sea states ≤ 3 .

Between 1999 and 2004, 17139 km were searched during systematic surveys conducted in the study area, of which 3937 km were inside the cMPA. From 2001 to 2004, tuna-fishing vessels conducted 1588 km of transects inside the cMPA and 34737 km outside. Opportunistic surveys provided a wider geographic distribution and greater amount of survey effort than systematic surveys. In spite of this, preliminary analysis of data collected by the two types of surveys produced similar spatial and temporal patterns of dolphin distribution. Therefore, the datasets were pooled and analysed together.

We calculated encounter rates of bottlenose dolphins to compare their relative abundance inside and outside the cMPA and to investigate if there was any evidence of

annual or seasonal changes in their distribution. For each area the encounter rate was calculated as the number of schools sighted on a given survey divided by the survey effort. Encounter rates were non-normally distributed so the square-root transformation of encounter rates was used to test the influence of temporal variables on dolphin relative abundance in each area using two-way analysis of variance.

To investigate if bottlenose dolphins showed fine-scale habitat preference for the cMPA compared to adjacent areas, the research site was divided into equal-sized cells, with a resolution of 10 nautical miles (343 km²) (Figure 3). The size of the grid cells was chosen to ensure that there was enough survey effort and dolphin sightings in each cell to allow estimation of sighting frequencies. Data of grids B2 and B3 were pooled into a single grid (B2+3) with approximately the same surface area of the other grids, after subtracting the cMPA. The observed sighting frequencies in each cell were compared to the expected sighting frequencies, calculated after taking into account the survey effort. The cMPA was initially treated as a single cell to compare patterns of habitat use inside the cMPA with those found outside the area. To investigate if there were preferred areas within the cMPA and to separate potential differences found between area (inside versus outside the cMPA) from differences acting at a smaller spatial scale, the cMPA was further subdivided into four zones. The expected sighting frequency of cell i , E_i , was calculated as:

$$E_i = n \times \frac{l_i}{L}$$

where n = total number of sightings of bottlenose dolphins, l_i = survey effort in grid cell i , and L = total survey effort. A log-likelihood ratio goodness of fit test was used to compare the observed frequency distribution of dolphin sightings across the grid cells with the expected distribution determined from the effort data.

Usage of the cMPA by the resident group

Previous work conducted in the same study area identified a group of 44 bottlenose dolphins that were frequently sighted within and between years in the channel between Faial and Pico and in the vicinity of these islands. In addition, these dolphins showed strong geographic fidelity to this area and were never encountered in other islands or in more offshore waters (Silva *et al.*, 2008). Based on these findings, these dolphins were classified as residents in the study area (Silva *et al.*, 2008). These authors estimated the size of the home range of 27 resident dolphins and assessed the degree of overlap of the home range between all possible pairs of dolphins. Here, we revisited the same dataset only to quantify the fraction of each resident dolphin's range included in the cMPA. We then estimated the range of the whole resident group composed of 44 dolphins, to quantify the fraction of the group's range included in the cMPA and to investigate if the resident group used the cMPA consistently within and between years.

Silva *et al.* (2008) provides a complete description of the procedures used to estimate the home range of individual dolphins. We used photo-identification data collected during systematic surveys conducted in the study area from March 1999 to October 2004. These surveys were designed to ensure as equal coverage as possible of the study area. Sighting locations of the resident group were plotted using *ArcView*® 3.2. A single data point was plotted per sighting, which means that all sightings were given equal weight regardless of the number of resident individuals present in the school.

1 The fixed kernel method (Worton, 1989), from the Animal Movement Analyst
2 Extension of *ArcView*® 3.2 (Hooge and Eichenlaub, 1997), was used to identify areas
3 of high-use by the resident group. The kernel is a probabilistic method that instead of
4 just reporting the size of the area used by the group is capable of assessing the group's
5 probability of occurrence at each point within its range (i.e., utilization distribution,
6 UD). We estimated the known range (95% UD) and core area (50% UD) of the resident
7 group for every year and season of study, after subtracting the area of landmasses from
8 all estimates.

9 The bandwidth value that determines the amount of smoothing applied to the
10 data was calculated through the least squares cross validation. The Schoener's ratio
11 (t^2/r^2 , where t^2 = mean squared distance between successive observations, and r^2 = mean
12 squared distance from the centre of activity) (Schoener, 1981) was calculated for each
13 year and season to estimate the degree of temporal autocorrelation in the data and assess
14 the potential negative bias on the kernel estimators. We tested the null hypothesis of
15 independence between successive sightings of the resident group using the test
16 developed by Swihart and Slade (1985) ($t^2/r^2 \geq 2$, significance level = 0.25 for one-tailed
17 test).

18 To understand whether the cMPA contained high-used areas for critical
19 activities, the home-range calculations were repeated using only encounters with
20 resident dolphins engaged in foraging and socializing/resting behaviour.

22 **RESULTS**

23 **Distribution and patterns of habitat use inside and outside the cMPA**

A total of 53464 km was surveyed in the study area from 1999 to 2004 (Table 1). There were no data from opportunistic surveys in 1999 and 2000, resulting in considerably less sighting effort in those years, especially outside the cMPA. The sighting effort covered the whole study area but was mainly concentrated around the islands (Figure 1). During surveys, 203 schools of bottlenose dolphins were sighted, of which 34 were encountered inside the cMPA and 169 outside this area (Table 1, Figure 3). Dolphin encounter rate was significantly higher inside (0.676 ± 0.141) than outside the cMPA (0.398 ± 0.041) (Mann-Whitney test, $U = 258587.0$, $P = 0.032$). Bottlenose dolphins were observed in the cMPA and surrounding area in all years and seasons. Season had no significant effect on dolphin encounter rate ($F_{(1,3)} = 0.446$, $P = 0.720$) but encounter rates varied among years ($F_{(1,5)} = 7.609$, $P < 0.001$), with significantly higher values in 1999 and 2000 in both areas (Newman-Keuls test, $P < 0.05$). Annual variations in encounter rate were similar inside and outside the cMPA ($F_{(1,5)} = 1.432$, $P = 0.210$).

Bottlenose dolphin schools encountered outside the cMPA were larger (mean = 15.1) than schools encountered in the cMPA (mean = 12.7) but differences were not significant (Mann-Whitney test, $U = 2503.0$, $P = 0.530$). There was no evidence of annual or seasonal variations in the mean size of schools using the cMPA and surrounding area (Kruskal-Wallis ANOVA, year: $H_{(5,196)} = 1.546$, $P = 0.908$; season: $H_{(3,196)} = 1.479$, $P = 0.687$).

Dolphins were not uniformly distributed across the study area. Several grid cells had higher sighting frequencies than expected by the distribution of survey effort, suggesting that there were parts of the study area more frequently used by the dolphins than others ($G = 48.199$, $P < 0.0001$) (Figure 3). Bottlenose dolphins showed a strong

1 preference for the cMPA, which had 80% more sightings ($n=34$) than what was
2 expected ($E=21.0$), and for the area contiguous to the cMPA (cells A2, A3, B2+3).
3 When the log-likelihood test was repeated using only these grid cells (cMPA, A2, A3,
4 B2+3), the observed sightings were equal to the expected sightings, indicating dolphins
5 did not prefer one area over the other ($G = 0.156$, $P = 0.693$). There was also no
6 evidence of high-use sub-areas within the cMPA ($G = 4.775$, $P = 0.189$).

7 To investigate if there were annual changes in the pattern of habitat use, the
8 observed and expected sighting frequencies of each grid cell were calculated separately
9 for each year. The mean ratio of observed to expected sighting frequencies and the
10 standard deviation of this ratio were used to assess intensity and persistence of use of
11 each grid cell. For three grid cells- north of Faial (A2), cMPA (P), and south of Pico
12 (C4) - the ratio of observed to expected frequencies was consistently greater than 1,
13 suggesting that dolphins always used these areas more often than predicted by the
14 survey effort (Figure 4). Of the three areas, the cMPA had the lowest mean ratio,
15 showing slightly lower intensity of use, but also had the lowest standard deviation,
16 indicating the area was used more consistently by bottlenose dolphins. Some grid cells,
17 e.g. A3, A4, C1 and C3, had mean ratios greater than 1 but showed a wide variation
18 (Figure 4). For the remaining cells the sighting frequencies recorded were always
19 smaller than predicted by the survey effort.

21 **Usage of the Marine Park by the resident group**

22 During the study period 287 systematic surveys were conducted and bottlenose
23 dolphins were encountered on 120 of these surveys. Of the 135 schools photographed in
24 the research area, 104 contained resident dolphins. The sighting histories and home

1 ranges of individual dolphins were presented elsewhere (Silva *et al.*, 2008). Mean home
2 range (95% UD) size of resident dolphins was 424 km² (179–1887 km²) and mean core
3 area (50% UD) was 84 km² (30–418 km²) (Silva *et al.*, 2008). Resident dolphins were
4 frequently sighted in the cMPA and the candidate protected area encompassed part of
5 the home range and core area of all dolphins studied. However, percentage of overlap of
6 individual's home ranges with the cMPA area varied greatly from 7 to 35%, with an
7 average of 25% (SD = 7.5%). As expected, percentage of overlap with the cMPA
8 decreased with increasing sizes of individual's home ranges (Spearman's rank
9 correlation, $r = -0.679$, $P < 0.001$). In contrast, there was no correlation between the size
10 of the core area of resident dolphins and the fraction of the core area overlapping the
11 cMPA (Spearman's rank correlation, $r = 0.042$, $P = 0.837$), suggesting great stability in
12 the use of the protected area. This also indicates that dolphins that maintain larger core
13 areas tend to do so by expanding their distribution into the cMPA. On average, about
14 39% (SD = 18%) of the core area of resident dolphins lay within the limits of the
15 cMPA.

16 Mean Schoener's ratio for annual and seasonal estimates of the home range of
17 the resident group was 1.73 (± 0.24) and 1.62 (± 0.12), respectively. Apart from 1999,
18 location data used in home range estimation showed no significant autocorrelation ($P >$
19 0.25). Schoener's ratio for 1999 was 1.0, which may result in a negative bias of 5–10%
20 in kernel estimators.

21 The kernel home range method produced a range for the whole resident group of
22 650 km² that included the area north and south of Faial up to 10 km from the coast, the
23 whole channel between Faial and Pico, and the area along the south-western coast of
24 Pico, up to 8 km from the coast (Figure 5). Within this range, the method highlighted a

1 core area of 95 km² located at the southern entrance of the channel between the islands
2 of Faial and Pico (Figure 5). Except for 2002, the range size of the resident group
3 showed little annual variation, varying from 483 km² to 657 km² (Figure 6). In contrast,
4 there were considerable seasonal differences, with dolphins expanding their range and
5 core areas in winter and summer and contracting them in the other seasons (Figure 7).
6 Annual and seasonal variations in the estimated range size were not related to the
7 amount of survey effort (Spearman's rank correlation, year: $r = 0.486$, $P = 0.329$;
8 season: $r = 0.800$, $P = 0.200$).

9 The resident group used 99% of the 123 km² of the surface area of the cMPA.
10 However, this represented <20% of the known range of the group. The southern
11 boundary of the cMPA crossed the core area of the resident group, encompassing nearly
12 42% (39 km²) of this high-use area (Figure 5). In the autumn of 2000 and 2003, the
13 kernel method identified a second core area, at the northern entrance of the channel.
14 Once again, only part (<30%) of this favoured area was included within the cMPA. The
15 resident group used the cMPA consistently throughout the study, despite some annual
16 and seasonal variations in the size of the overlapping region (Figures 6 and 7).

17 The home-range calculations were repeated using the initial location of
18 encounters with resident dolphins only engaged in foraging and socializing/resting
19 behaviours, using data from all years and seasons pooled together. The areas used for
20 foraging and social activities largely overlapped but foraging was more concentrated at
21 both entrances of the channel, while socializing/resting was mainly observed in the
22 southern entrance and south of Pico island. Approximately 21% of the area used for
23 foraging and 11% of the area used for socializing/resting lay within the cMPA.

DISCUSSION

The present work shows the area delimited by the cMPA of the Faial-Pico channel is important habitat for the population of bottlenose dolphins frequenting the region and is used with similar intensity year-round. Between-year variability on the encounter rate inside and outside the cMPA were similar and likely reflects natural fluctuations in the overall distribution and abundance of bottlenose dolphins in the region, which may be related to temporal changes in prey density and availability.

Bottlenose dolphins showed a consistent pattern of low or high-use of some areas throughout the years, suggesting fine-scale habitat preferences within the study site. Sightings were higher than expected in all years of study in the cMPA, north of Faial and south-east of Pico, whereas dolphins tended to avoid the regions north of S. Jorge and east of Pico, the deep channel (>1000 m) between Pico and S. Jorge, as well as more offshore waters. There was no evidence of favoured areas within the cMPA.

Bottlenose dolphins often seek and associate with environmental features known to enhance biological productivity or promote prey aggregation (Baumgartner *et al.*, 2001; Cañadas *et al.*, 2002, 2005). There is no information on the distribution of potential prey species of bottlenose dolphins in the study area. However, remote sensing data revealed that some of the areas regularly used by these dolphins were among the most biologically productive areas of the Azores. Chlorophyll-*a* concentration within a 5-km region around Faial and the western side of Pico was found to be 4 to 6 times larger than those found elsewhere in the archipelago (Tempera, 2009). Enhanced primary productivity was consistently observed off the north-western coast of Faial, in the channel Faial-Pico, and in a narrow fringe along Faial's northern shore (Tempera, 2009). Increased primary productivity in these areas would also give rise to an increase

1 of zooplankton and fish populations, which would help in explaining the dolphins'
2 habitat preferences and persistent use of these areas over the years. In addition, the three
3 sites favoured by the population have comparatively wider shelves than the rest of the
4 research area. Shallower areas may lead to increased foraging opportunities, by
5 facilitating prey capture and allowing bottlenose dolphins to take advantage of bottom
6 fishes in addition to schooling prey.

7 In addition to containing suitable foraging habitat and being routinely used by
8 bottlenose dolphins frequenting the study site, the cMPA encompasses the home range
9 of a small group of dolphins residing in the area around Faial and Pico. The typical
10 range of the group was centred in the Faial-Pico channel but also included coastal areas
11 north and south of Faial, and south-west of Pico. With a surface area of 123 km² the
12 cMPA is clearly too small to cover the whole range of the group estimated to be of 650
13 km².

14 The known range of the resident group was reasonably constant across years. In
15 contrast, there were noticeable differences in range size between seasons, with animals
16 expanding their range in winter and summer and contracting it in spring and autumn.
17 Interestingly, the range contraction coincided with reported peaks in primary
18 productivity at these times (Tempera, 2009), which may attract and concentrate prey
19 species into relatively small areas.

20 Animals do not use all parts of their home range with equal intensity. Within
21 animals' ranges, core areas likely contain the most reliable food resources and may also
22 provide important refuges (Samuel *et al.*, 1985). The resident group's range contained
23 two distinct core areas situated at both entrances of the Faial-Pico channel. The southern
24 entrance was a favoured area in all years and seasons and was also the most intensively

1 used part of the range for feeding and socializing/resting, even though dolphins used a
2 wider area when engaged in social activities. Aside from the potential importance of this
3 area for social activities, consistent use of the southern entrance core area suggests the
4 presence of a profitable foraging spot and its persistence through time suggests a
5 relatively stable system within a dynamic open ocean habitat.

7 **Usefulness of the cMPA as a management tool**

8 MPAs have the potential to protect cetacean populations, provided they include
9 important habitat areas used for life-history processes (e.g. feeding, breeding, calving,
10 migrating) and are large enough to be ecologically relevant to the population concerned.
11 Thus, the usefulness of a MPA as a management tool will depend to a large degree on
12 our ability to identify and delineate spatially and temporally appropriate boundaries
13 around these critical areas (Williams *et al.*, 2009; Ashe *et al.*, 2010).

14 This study shows that bottlenose dolphins routinely used the area delimited by
15 the cMPA and that this area encompasses a fraction of the typical range of a small group
16 of resident dolphins living in the study site. Although dolphins also used other areas in
17 the vicinity, the reliability in the use of the channel between Faial and Pico over a 6-
18 year period suggests that its importance for the whole population and particularly for the
19 resident group remains relatively stable, making it a suitable candidate for site-based
20 management.

21 However, this study also demonstrates that the area covered by the cMPA is
22 clearly insufficient to satisfy the spatial requirements of the resident group. More
23 importantly, the cMPA does not encompass the totality of the group's core area that

1 constitutes critical habitat for essential activities such as foraging or socializing and
2 resting.

3 The range and core areas of the resident group are intensely used by whale-
4 watching operators and dolphins are exposed to these boats on a daily basis. Several
5 studies have documented short-term behavioural changes in cetacean populations
6 associated with the whale-watching activity, including alterations in movement,
7 respiration and diving patterns, or group cohesion (reviewed in Lusseau and Bejder,
8 2007). Furthermore, there is increasing evidence that these short-term reactions can
9 have long-term consequences for individuals and populations. Disturbance from whale-
10 watching boats was shown to be responsible for long-term habitat displacements in
11 bottlenose dolphins, as well as for declines in abundance and reproductive rates
12 (Lusseau, 2005; Bejder *et al.*, 2006; Lusseau *et al.*, 2006). Populations that are resident
13 in whale-watching areas are more likely to be adversely affected because repeated
14 encounters with whale-watching boats may result in chronic stress and/or repeated
15 disruption of critical behaviours, such as feeding, resting and breeding (Bejder and
16 Samuels, 2003). This may eventually lead to reduced fitness of individuals (for example
17 through reduced reproductive or foraging success) and threaten the viability of the
18 group (Lusseau and Bejder, 2007).

19 Scaling the cMPA to include the core areas of the resident group while
20 controlling the number of whale-watching boats operating inside the cMPA, could
21 reduce the frequency and duration of encounters of resident individuals with boats,
22 decrease the likelihood of disruption of important behavioural activities, and diminish
23 the long-term cumulative impacts on this group. Including the core area would also
24 afford protection to the most important foraging habitat of this small group. While their

1 reliance on the area delimited by the cMPA is lower, non-resident dolphins would also
2 benefit from enhanced protection to important foraging sites and diminished exposure to
3 whale-watching boats.

4 **Alternative designs for the MPA**

6 Based on the findings of this study, in 2006, the University of the Azores made a
7 proposal to the Regional Government to extend the cMPA. The explicit justification for
8 the enlargement of this cMPA was that high priority habitat areas for the resident group
9 were left outside the protected area. Two different designs were submitted for
10 discussion with the regional authorities: 1) Scenario A proposed to expand the southern
11 boundary of the cMPA to include the whole southern core area of the resident group; 2)
12 Scenario B proposed to expand all the boundaries of the cMPA to account for the
13 observed seasonal variations in the core area of the resident group (including the
14 secondary core area identified at the northern entrance of the channel) and include part
15 of the areas used more intensely and persistently by bottlenose dolphins (grid cells A2,
16 A3, B2+3) (Figure 5). The rectangular shapes were proposed for practical reasons, so it
17 would be easier to be aware of the limits of the areas by following latitude and
18 longitude straight lines.

19 Scenario A was accepted by the Azorean Regional Government and established
20 as a MPA in 2008. The MPA includes the whole southern core area of the resident
21 group of bottlenose dolphins and 37% of their known range. To the best of our
22 knowledge, this is the only case of a MPA designed to include 100% of the core area of
23 a population of cetaceans.

1 The establishment of MPAs is often grounded on political rather than scientific
2 principles, limiting their value as management tools. Frequently, the boundaries are set
3 arbitrarily without strong knowledge of the distribution and behaviour of the population
4 of interest and once the area is set there is no attempt to evaluate its effectiveness
5 (Agardy *et al.*, 2003). The establishment of a MPA that encompasses the whole core
6 range of the resident group of bottlenose dolphins represents a powerful management
7 tool that can be used to minimize area-specific threats, such as chronic exposure to the
8 whale-watching activity. However, extending the boundaries of the cMPA to include
9 habitat areas important to the resident group will hardly achieve anything unless a set of
10 management objectives is defined for this group and management actions are
11 implemented. It is therefore essential and urgent to develop a management plan that
12 establishes achievable conservation targets for the resident group, identifies a series of
13 management actions to accomplish those, and includes a monitoring programme to
14 measure the effectiveness of the actions in achieving the targets.

15 This study provides an example of how to identify habitat areas of special
16 interest for cetacean conservation and how information on the space-use patterns may
17 be used to design ecologically meaningful protected areas. The present work is not an
18 integral part of a framework for systematic conservation planning (Margules and
19 Pressey, 2000). Still, it provides a good example of how research can and should assist
20 in implementing conservation policies (Knight *et al.*, 2006, 2008).

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Figure captions:

Figure 1 – Map showing the location of the study area, the boundaries of the cMPA and the tracks of systematic and opportunistic surveys conducted from 1999 to 2004. Inset shows the location of the three Sites of Community Importance (SCI) designated in 2001 within the framework of European Union's (EU) Habitats Directive.

Figure 2 – Examples of 'Good' (A), 'Fair' (B) and 'Poor' (C) quality photographs of dolphin Ttr79. Only photographs graded as "Good" were used in this study.

Figure 3 – Distribution of survey effort per grid cell and location of sightings of bottlenose dolphins (black dots). Effort and sighting data of grids B2 and B3 were pooled into a single grid (B2+3) with approximately the same surface area of the other grids, after subtracting the cMPA (inset area).

Figure 4 – Mean ratio of observed to expected sighting frequencies in each grid cell within the study area. Ratios were calculated separately for each year. Effort and sighting data of grid cells B2 and B3 were pooled into a single grid cell (B2+3) with approximately the same surface area of the other grid cells, after subtracting the cMPA. Vertical bars represent mean \pm standard deviation.

Figure 5 – Known range (95% UD in dark grey) and core area (50% UD in white) of the resident group, estimated by the fixed kernel method. The rectangles represent the limits

of the cMPA, and of the two alternative designs proposed - Scenario A (accepted) and Scenario B (rejected) - to expand the cMPA.

Figure 6 – Annual variation in the known range (95% UD) and core area (50% UD) of the resident group and percentage of overlap with the cMPA.

Figure 7 – Seasonal variation in the known range (95% UD) and core area (50% UD) of the resident group and percentage of overlap with the cMPA.

1 Table 1 – Survey effort (km) and number of schools of bottlenose dolphins encountered
2 per year inside and outside the cMPA.

Year	cMPA		Outside		Total	
	Effort	Schools	Effort	Schools	Effort	Schools
1999	408	2	1131	6	1539	8
2000	688	10	2058	14	2746	24
2001	1230	2	13390	31	14620	33
2002	1132	4	10356	37	11488	41
2003	1056	9	10011	40	11067	49
2004	1012	7	10994	41	12006	48
Total	5525	34	47939	169	53464	203

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